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**DIVISIONAL  
APPLICATION  
FOR  
UNITED STATES  
LETTERS PATENT**

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**FOR:** **OPTICAL AMPLIFYING AND RELAYING  
SYSTEM**

**DOCKET NO.:** **2001P078308 DIV2**

OPTICAL AMPLIFYING AND RELAYING SYSTEM

BACKGROUND OF THE INVENTION

This application claims benefit of Japanese Patent Application No. 2001-078308 filed on March 19, 2001, the  
5 contents of which are incorporated by the reference.

The present invention relates to optical amplifying and relaying systems and, more particularly, to optical amplifying and relaying systems for amplifying light signals in optical fiber transmission  
10 lines or the like and also monitoring the transmission line state.

The optical communication utilizing optical fibers has various merits compared to conventional electric communication with electric signals through the copper  
15 wire. Particularly, the optical communication can be adopted for high rate and large capacity communication and is excellent in anti-noise characteristics against electromagnetic noise or the like. In the optical communication, coherent light beams such as laser beams  
20 are transmitted on very thin optical fiber cables. Although the optical fiber cable has low optical attenuation characteristic and permits long distance transmission, in order to maintain the signal quality the light signal is amplified by optical  
25 amplifier/relays provided at a predetermined interval. Prior art techniques in such technical field are disclosed in Japanese Patent Laid-Open No. 9-116502 entitled "High Output Optical Amplifier/Relay having

monitoring Loop-Back Circuit", Japanese Patent Laid-Open No. 9-153862 entitled "Monitoring Method in Optical Amplifying/Relaying Transmission System" and Japanese Patent Laid-Open No. 2000-59306 entitled "Optical  
5 Amplifier/Relay" and so forth.

Fig. 17 is a block diagram showing the structure of a prior art optical amplifier/relay (or optical amplifying and relaying system). This optical amplifier/relay 1 comprises a first and a second optical  
10 amplifier 2a and 2b, a first (optical) coupler 3a, a second coupler 3b, a first and a second wavelength selective reflecting means 5a and 5b and a first and a second terminal part 6a and 6b. In this prior art technique, light branching/wavelength selective  
15 reflecting means connected at subsequent stages to the optical amplifiers 2a and 2b in paired optical transmission lines for transmission and reception, transmit monitoring signals to the opposite lines.

Fig. 18 is a view illustrating operation of the optical amplifier/relay shown in Fig. 17 in the case of  
20 transmitting monitoring light signals to the opposite optical transmission lines for the monitoring thereof. In this optical amplifier/relay, in the optical transmission line a monitoring light signal ( $\lambda_{sv}$ ) and  
25 a main light signal ( $\lambda_1$  to  $\lambda_4$ ) are inputted to the optical amplifier 2a and transmitted via subsequent stage optical branching function constituted by the first optical coupler 3a, the wavelength selective reflecting

means 5a and the second coupler 3b to the opposite optical transmission line, and monitoring light signal ( $\lambda_{sv}$ ) and the reflectivity of the optical grating are obtained on the opposite optical transmission line side.

5        In this optical amplifier/relay, the light intensity variation in the optical amplifier in each line and the light intensity variation of the monitoring light signal transmitted to the opposite line are equal. In this case, a problem arises in the event of a trouble  
10       occurred in the optical amplifier, the output of which is subject to very little variation, that the trouble can not be recognized or that the recognition requires long time. Also, the monitoring light signal folded back to the opposite line permits obtaining only data  
15       concerning the output level of the optical amplifier.

#### SUMMARY OF THE INVENTION

      An object of the present invention, accordingly, is to provide a high accuracy optical amplifying and relaying system capable of solving or alleviating the  
20       above problem inherent in the prior art.

      According to a first aspect of the present invention, there is provided an optical amplifying and relaying system comprising an up and a down optical transmission line opposing each other, amplifiers each  
25       provided on each of the optical transmission lines, and monitoring light signal folding-back lines connected between the two optical transmission lines and each including an optical coupler for taking out a monitoring

light signal led to the own optical transmission line and a wavelength selective reflecting means for transmitting the monitoring light signal received from the own optical transmission line by folding-back  
5 transmission to the opposite optical transmission line, wherein: the optical amplifying and relaying system further comprises variable optical attenuators each provided between each optical coupler and the associated wavelength selective reflecting means.

10 The optical couplers are each provided on the optical transmission line in the output side of each optical amplifier. The optical couplers are each provided on the optical transmission line on the input side of each optical amplifier. Wavelength selective  
15 reflecting means are provided two on opposites of each of the variable optical attenuators, the two wavelength selective reflecting means being operative to reflect light signals of different wavelengths for transmission to the opposite optical transmission line. The  
20 monitoring light signal folding-back lines each include a pair of lines for transmitting a light signal from the output side of the optical amplifier on the own optical transmission line to the input side of the optical amplifier on the opposite optical transmission line. A  
25 light signal led to each monitoring light signal folding-back line is transmitted via a separate optical coupler and wavelength selective reflecting means of different wavelengths to the opposite optical

transmission line.

According to a second aspect of the present invention, there is provided an optical amplifying and relaying system comprising an up and a down optical transmission line opposing each other, amplifiers each provided on each of the optical transmission lines, and monitoring light signal folding-back lines connected between the two optical transmission lines and each including an optical coupler for taking out a monitoring light signal led to the own optical transmission line and a wavelength selective reflecting means for transmitting the monitoring light signal received from the own optical transmission line by folding-back transmission to the opposite optical transmission line, wherein variable optical attenuators are each provided between each optical coupler and the associated wavelength selective reflecting means, the monitoring light signal branched and reflected by the optical coupler on each optical transmission line being transmitted via the optical coupler on the opposite optical transmission line to the optical amplifier output side thereof.

According to a third aspect of the present invention, there is provided an optical amplifying and relaying system comprising an up and a down optical transmission line opposing each other, amplifiers each provided on each of the optical transmission lines, and monitoring light signal folding-back lines connected

between the two optical transmission lines and each including an optical coupler for taking out a monitoring light signal led to the own optical transmission line and a wavelength selective reflecting means for  
5 transmitting the monitoring light signal received from the own optical transmission line by folding-back transmission to the opposite optical transmission line, wherein variable optical attenuators are each provided between each optical coupler and the associated  
10 wavelength selective reflecting means, the monitoring light signal folding-back lines are each provided on the input side of the optical amplifier on the own optical transmission line.

According to a fourth aspect of the present  
15 invention, there is provided an optical amplifying and relaying system comprising an up and a down optical transmission line opposing each other, amplifiers each provided on each of the optical transmission lines, and  
monitoring light signal folding-back lines connected  
20 between the two optical transmission lines and each including an optical coupler for taking out a monitoring light signal led to the own optical transmission line and a wavelength selective reflecting means for  
transmitting the monitoring light signal received from  
25 the own optical transmission line by folding-back transmission to the opposite optical transmission line, wherein variable optical attenuators are each provided between each optical coupler and the associated



wavelength selective reflecting means, and the monitoring light signal branched and reflected by each coupler on optical amplifier output side of the own optical transmission line is transmitted via the optical  
5 coupler and optical amplifier input side on the opposite optical transmission line to the same opposite optical transmission line.

According to a fifth aspect of the present invention, there is provided an optical amplifying and  
10 relaying system comprising an up and a down optical transmission line opposing each other, amplifiers each provided on each of the optical transmission lines, and monitoring light signal folding-back lines connected between the two optical transmission lines and each  
15 including an optical coupler for taking out a monitoring light signal led to the own optical transmission line and a wavelength selective reflecting means for transmitting the monitoring light signal received from the own optical transmission line by folding-back  
20 transmission to the opposite optical transmission line, wherein variable optical attenuators are each provided between each optical coupler and the associated wavelength selective reflecting means, and optical couplers are provided on the output and input sides of  
25 each optical amplifier, and the branched and reflected monitoring light signals on each optical transmission line side are transmitted via the output and input sides, respectively, of the optical amplifier on the opposite

optical transmission line to the same opposite optical transmission line.

According to a sixth aspect of the present invention, there is provided an optical amplifying and relaying system comprising an up and a down optical transmission line opposing each other, amplifiers each provided on each of the optical transmission lines, and monitoring light signal folding-back lines connected between the two optical transmission lines and each including an optical coupler for taking out a monitoring light signal led to the own optical transmission line and a wavelength selective reflecting means for transmitting the monitoring light signal received from the own optical transmission line by folding-back transmission to the opposite optical transmission line, wherein variable optical attenuators are each provided between each optical coupler and the associated wavelength selective reflecting means, and on each optical transmission line a monitoring light signal branched and reflected by an optical amplifier output side optical coupler via an optical coupler and the optical amplifier input side on the opposite transmission line to the same opposite optical transmission line, while a monitoring light signal branched and reflected by an optical amplifier output side on the opposite optical transmission line to the same opposite optical transmission line.

According to a seventh aspect of the present

invention, there is provided an optical amplifying and relaying system comprising an up and a down optical transmission line opposing each other, amplifiers each provided on each of the optical transmission lines, and  
5 monitoring light signal folding-back lines connected between the two optical transmission lines and each including an optical coupler for taking out a monitoring light signal led to the own optical transmission line and a wavelength selective reflecting means for  
10 transmitting the monitoring light signal received from the own optical transmission line by folding-back transmission to the opposite optical transmission line, wherein variable optical attenuators are each provided between each optical coupler and the associated  
15 wavelength selective reflecting means, and on each optical transmission line the light signal led to the monitoring light signal folding-back line is branched by a separate optical coupler, then reflected by a plurality of wavelength selective reflecting means of  
20 different wavelengths and then transmitted to the opposite optical transmission line.

Wavelength selective reflecting means is provided preceding to and subsequent to the variable optical attenuator. An optical isolator is provided as an  
25 intermediate stage in each monitoring light signal folding-back line, and each wavelength selective reflecting means uses an optical fiber grating.

Other objects and features will be clarified from

the following description with reference to attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing the structure of  
5 a first embodiment of the optical amplifying and relaying  
system according to the present invention;

Fig. 2 is a view showing the structure of a second  
embodiment of the optical amplifying and relaying system  
according to the present invention;

10 Fig. 3 is a view showing the structure of a third  
embodiment of the optical amplifying and relaying system  
according to the present invention;

Fig. 4 is a view showing a fourth embodiment of the  
optical amplifying and relaying system according to the  
15 present invention;

Fig. 5 is a view showing the structure of a fifth  
embodiment of the optical amplifying and relaying system  
according to the present invention;

Fig. 6 is a view showing the structure of a sixth  
20 embodiment of the optical amplifying and relaying system  
according to the present invention;

Fig. 7 is a view showing the structure of a seventh  
embodiment of the optical amplifying and relaying system  
according to the present invention;

25 Fig. 8 is a view showing the structure of an eighth  
embodiment of the optical amplifying and relaying system  
according to the present invention;

Fig. 9 is a view showing the structure of a ninth

embodiment of the optical amplifying and relaying system according to the present invention;

Fig. 10 is a view showing the structure of a tenth embodiment of the optical amplifying and relaying system according to the present invention;

Fig. 11 is a view showing an eleventh embodiment of the optical amplifying and relaying system according to the present invention;

Fig. 12 is a view showing the structure of a twelfth embodiment of the optical amplifying and relaying system according to the present invention;

Fig. 13 is a view showing the structure of a thirteenth embodiment of the optical amplifying and relaying system according to the present invention;

Fig. 14 is a view showing the structure of a fourteenth embodiment of the optical amplifying and relaying system according to the present invention;

Fig. 15 shows the operation of transmission of the monitoring light signals in the optical amplifying and relaying system according to the present invention to the opposite lines;

Fig. 16 shows an example of the level characteristic of the monitoring light signals folded back to the opposite lines in the optical amplifying and relaying system according to the present invention;

Fig. 17 is a block diagram showing the structure of a prior art optical amplifier/relay (or optical amplifying and relaying system); and

Fig. 18 is a view illustrating operation of the optical amplifier/relay shown in Fig. 17.

#### PREFERRED EMBODIMENTS OF THE INVENTION

Preferred embodiments of the present invention  
5 will now be described with reference to the drawings.  
For the sake of the brevity, elements corresponding to those in the prior art described above are designated by like reference numerals.

Fig. 1 is a block diagram showing the structure of  
10 a first embodiment of the optical amplifying and relaying system according to the present invention. The illustrated first embodiment of the optical amplifying and relaying system 1A includes two (or a pair of) optical amplifiers, i.e., an up and a down line optical amplifiers  
15 2a and 2b corresponding to an up and a down optical fiber transmission lines L1 and L2, respectively. As stages subsequent to the two optical amplifiers 2a and 2b are provided optical couplers (or optical branchers) 3a and 3b, variable optical attenuators 4a and 4b, wavelength  
20 selective reflecting means 5a and 5b, terminal parts 6a and 6b and a fixed attenuator 7. In this specification, by the term "optical coupler" is generally referred to as an optical function element having a function of branching and combining light. The fixed attenuator 7  
25 is not essential.

The optical couplers 3a and 3b each branch a main and a monitoring output light signal. The variable optical attenuators 4a and 4b adjust the light intensity

levels of the light signals branched by the optical couplers 3a and 3b. The wavelength selective reflecting means 5a and 5b transmit (pass) only the main light signals outputted from the variable optical attenuators 4a and 4b and reflect only the monitoring light signals therefrom. The monitoring light signals reflected by the wavelength selective reflecting means 5a and 5b pass through the variable optical attenuators 4a and 4b again, thence pass through the fixed attenuator 7 and thence fed out via the output side optical couplers 3b and 3a and optical amplifiers 2b and 2a, respectively, to the opposite optical fiber transmission lines L2 and L1.

Fig. 15 shows the operation of transmission of the monitoring light signals ( $\lambda_{sv}$ ) in the optical amplifying and relaying system 1A according to the present invention to the opposite lines. The optical coupler 3a branches part of the main and monitoring light signals ( $\lambda_1$  to  $\lambda_4$ ) and ( $\lambda_{sv}$ ) outputted from the optical amplifier 2a from the opposite optical fiber transmission line. The main and monitoring light signals ( $\lambda_1$  to  $\lambda_4$ ) and ( $\lambda_{sv}$ ) branched by the optical coupler 3a pass through the variable optical attenuator 4a and fed to the wavelength selective reflecting means 5a, which transmits only the main light signal ( $\lambda_1$  to  $\lambda_4$ ) and reflects only the monitoring light signal ( $\lambda_{sv}$ ). The monitoring light signal ( $\lambda_{sv}$ ) reflected by the wavelength selective reflecting means 5a passes through the variable optical attenuator 4a again, and fed out by the optical coupler

3b provided on the output side of the opposite optical amplifier 2b to the opposite optical fiber transmission line. The attenuation level of the variable optical attenuator 4a (which prescribes the level of the monitoring light signal fed out to the opposite optical fiber transmission line) is a predetermined according to the state of the optical amplifier 2a (for instance, large when the number of troubles in an excited laser diode is increased or when the optical amplifier input level is reduced), and it is possible to determine the state of the optical amplifying and relaying system 1A in an optical amplifying and relaying system monitor (not shown) installed in a terminal station.

Fig. 16 shows an example of the level characteristic of the monitoring light signals folded back to the opposite lines when setting the attenuation level of the variable optical attenuators 4a and 4b based on the output state of the exciting laser diode LD in the optical amplifying and relaying system 1A shown in Fig. 1. State A shows the optical attenuation level and the monitoring light signal level of the variable optical attenuator 4a when the output level of the exciting LD is a rated level. In this state, the attenuation level of the monitoring light signal is 0 dB, and the level thereto is an initial level. State B shows the optical attenuation level and the monitoring light signal level of the variable optical attenuator 4a when the output level of the exciting LD is reduced to one half. In this



state, the attenuation level of the monitoring light signal is -3 dB with respect to the initial level. State C shows the optical attenuation level and the monitoring light signal level of the variable optical attenuator 4a when the output of the exciting LD is turned off. In this state, the attenuation level of the monitoring light signal is -6 dB with respect to the initial level. The state of the exciting LD in the optical amplifying and relaying system 1A can be monitored by determining the different light signal levels with the above terminal station monitor.

Fig. 2 is a view showing the structure of a second embodiment of the optical amplifying and relaying system according to the present invention. The second embodiment of the optical amplifying and relaying system 1B comprises, in addition to all the elements in the first embodiment shown in Fig. 1, wavelength selective reflecting means 5a and 5c, and 5b and 5d provided preceding to and succeeding to the variable optical attenuators 4a and 4b, respectively. The two pairs of wavelength selective reflecting means 5a and 5c, and 5b and 5d, reflect different wavelength monitoring light signals to be transmitted to the opposite lines L2 and L1. It is possible to make highly accurate measurement of the attenuation levels of the variable optical attenuators by determining the levels of the transmitted monitoring light signals of the two different wavelengths.

Fig. 3 is a view showing the structure of a third embodiment of the optical amplifying and relaying system according to the present invention. This optical amplifying and relaying system 1C is the same in structure as the first embodiment of the optical amplifying and relaying system 1A shown in Fig. 1 except for that the monitoring light signal folding-back lines are provided not as succeeding stage (i.e., on the output side) but on the input side of the up and down optical amplifiers 2a and 2b.

Fig. 4 is a view showing a fourth embodiment of the optical amplifying and relaying system according to the present invention. This optical amplifying and relaying system 1D is a combination of the previous second and third embodiments of the optical amplifying and relaying systems 1B and 1C. More specifically, the monitoring light signal folding-back lines are provided in the input side of the up and down optical amplifiers 2a and 2b, respectively, and the wavelength selective reflecting means 5a and 5c and 5b and 5d are provided preceding to and succeeding to the variable optical attenuators 4a and 4b.

Fig. 5 is a view showing the structure of a fifth embodiment of the optical amplifying and relaying system according to the present invention. This optical amplifying and relaying system 1E further comprises optical couplers 3d and 3c, which transmit monitoring light signals having been branched and reflected on the

output side of the optical amplifiers 2a and 2b via the opposite optical amplifiers 2b and 2a to the opposite optical fiber transmission lines L2 and L1.

Fig. 6 is a view showing the structure of a sixth embodiment of the optical amplifying and relaying system according to the present invention. This optical amplifying and relaying system 1F, like the optical amplifying and relaying system 1E shown in Fig. 5, further comprises optical couplers 3c and 3d, which transmit monitoring light signals having been branched and reflected on the output side of the optical amplifiers 2a and 2b via the opposite optical amplifiers 2b and 2a to the opposite optical fiber transmission lines L2 and L1. This embodiment of the system 1F, like the Fig. 2 system, further comprises wavelength selective reflecting means 5a and 5c, and 5b and 5d provided preceding to and succeeding to the variable optical attenuators 4a and 4b.

Fig. 7 is a view showing the structure of a seventh embodiment of the optical amplifying and relaying system according to the present invention. This optical amplifying and relaying system 1G comprises optical couplers 3a and 3c, and 3b and 3d provided on the output and input sides of the optical amplifiers 2a and 2b, respectively. The branched and reflected monitoring light signals are transmitted not via and via the opposite optical amplifiers 2b and 2a to the opposite optical fiber transmission lines L2 and L1.

Fig. 8 is a view showing the structure of an eighth embodiment of the optical amplifying and relaying system according to the present invention. This optical amplifying and relaying system 1H, like the optical  
5 amplifying and relaying system 1G shown in Fig. 7, comprises optical couplers 3a to 3d, which are provided on the output and input sides of the optical amplifiers 2a and 2b and transmit the branched and reflected monitoring light signals via the opposite optical  
10 amplifiers 2b and 2a to the opposite optical fiber transmission lines L2 and L1. Also, like the Fig. 2 system, this embodiment of the system 1H further comprises wavelength selective reflecting means 5a and 5e, 5b and 5f, 5a and 5g, and 5d and 5h provided preceding  
15 to and succeeding to the variable optical attenuators 4a to 4d.

Fig. 9 is a view showing the structure of a ninth embodiment of the optical amplifying and relaying system according to the present invention. In this optical  
20 amplifying and relaying system 1I, the monitoring light signals branched and reflected by the optical couplers (or branchers) 3a and 3b on the output side of the optical amplifiers 2a and 2b, are transmitted via optical  
couplers 3d and 3c to the optical amplifiers 2b and 2a  
25 on the opposite optical fiber transmission lines L2 and L1. Also, the monitoring light signals branched and reflected by optical couplers 3c and 3d on the input side of the optical amplifiers 2a and 2b are transmitted via

the optical couplers 3c and 3d to the output side of the optical amplifiers 2b and 2a on the opposite optical fiber transmission lines L2 and L1.

Fig. 10 is a view showing the structure of a tenth embodiment of the optical amplifying and relaying system according to the present invention. In the optical amplifying and relaying system 1J, the monitoring light signals branched and reflected on the output side of the optical amplifiers 2a and 2b are transmitted via the opposite optical amplifiers 3d, 3c to the opposite optical fiber transmission lines, and the monitoring light signals branched and reflected on the input side of the optical amplifiers 2b and 2a are transmitted via the opposite optical amplifiers to the opposite optical fiber transmission lines L2 and L1. Also, wavelength selective reflecting means 5a and 5c, 5b and 5d, 5e and 5g, and 5f and 5h are provided preceding to and succeeding to the variable optical attenuators 4a to 4d.

Fig. 11 is a view showing an eleventh embodiment of the optical amplifying and relaying system according to the present invention. In this optical amplifying and relaying system 1K, the light signals led via optical couplers (or branchers) 3a and 3b to the monitoring light signal folding-back lines, are taken out by separator optical couplers (or branchers) 3c and 3d and reflected by a plurality of wavelength selective reflecting means 5a and 5b of different wavelengths to be transmitted to the opposite lines L2 and L1. This structure permits

monitoring data of a plurality of optical amplifying and relaying systems.

Fig. 12 is a view showing the structure of a twelfth embodiment of the optical amplifying and relaying system according to the present invention. In this optical amplifying and relaying system 1L, like the Fig. 11 system, the main light signals led via the optical couplers 3a and 3b to the monitoring light signal folding-back lines are taken out by the optical couplers 3c and 3d and transmitted by the wavelength selective reflecting means 5a and 5b of different wavelengths to the opposite lines L2 and L1. This structure thus permits monitoring data of a plurality of optical amplifying and relaying systems. Furthermore, wavelength selective reflecting means 5c and 5d are provided preceding to the optical couplers (or branchers) 3c and 3d, thus permitting highly accurate optical attenuation level monitoring.

Fig. 13 is a view showing the structure of a thirteenth embodiment of the optical amplifying and relaying system according to the present invention. In this optical amplifying and relaying system 1M, the monitoring light signals branched and reflected by optical couplers (or branchers) 3a and 3b on the output side of optical amplifiers 2a and 2b are transmitted by optical couplers 3c and 3d via optical amplifiers 2b and 2a to the opposite optical fiber transmission lines L2 and L1. The system 1M also comprises wavelength selective reflecting means 5a and 5c, and 5b to 5d. Main

light signals inputted to the optical amplifiers 2a and 2b are branched by optical couplers (or branchers) on the input side of the optical amplifiers 2a and 2b, and the branched light signals are inputted to PDs (i.e., photo-diodes). The optical attenuation levels of the variable optical attenuators 4a and 4b are controlled based on the output levels of the PDs.

Fig. 14 is a view showing the structure of a fourteenth embodiment of the optical amplifying and relaying system according to the present invention. In this optical amplifying and relaying system 1N, optical isolators 8a and 8b are provided as intermediate stages in the monitoring light signal folding-back lines. The wavelength selective reflecting means 5a and 5b adopt optical fiber gratings. The system 1N further uses optical couplers 3a to 3d.

As has been described in the foregoing, with the optical amplifying and relaying system according to the present invention the following practical pronounced effects are obtainable. More specifically, in an optical transmission system comprising an up and a down optical fiber transmission line opposing each other, terminal stations installed at the opposite terminals of these lines and a plurality of optical amplifying and relaying systems cascade connected between the optical fiber transmission lines, variable optical attenuators may be provided in monitoring light signal folding circuits installed in the individual optical amplifiers

for easily and highly accurately determining the levels  
of the monitoring light signals folded back to the  
opposite lines in dependence on the state of the optical  
amplifying and relaying system to be monitored. It is  
5 further possible to monitor a plurality of data of the  
optical amplifying and relaying systems.

Changes in construction will occur to those skilled  
in the art and various apparently different modifications  
and embodiments may be made without departing from the  
10 scope of the present invention. The matter set forth in  
the foregoing description and accompanying drawings is  
offered by way of illustration only. It is therefore  
intended that the foregoing description be regarded as  
illustrative rather than limiting.

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